REMINDINGS IN DECLARATIVE CONCEPT LEARNING

by

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As members of the Master's Committee, we certify that we have read the thesis prepared by Di Zhang, titled Remindings in Declarative Concept Learning and recommend that it be accepted as fulfilling the dissertation requirement for the Master's Degree.

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Abstract: Remindings are a fundamental building block of cognition that prompt people to retrieve relevant experiences when faced with novel stimuli. Remindings may allow learners to generalize across the common aspects of the earlier learning instance and the current one to gain the knowledge that will be used in the later categorization. The benefits of remindings in category knowledge have been well-established in the literature, yet the effectiveness of remindings in learning declarative concepts remains an open question. The goal of the thesis is to assess the role of remindings in near transfer and far transfer in learning declarative concepts. Across two experiments, remindings were encouraged by presenting new examples that were similar to prior studied examples, or remindings were discouraged by presenting new examples that were different than previously studied examples. However, across both experiments, no evidence was found that similar or different novel examples enabled different amounts of remindings. Further, no significant differences were found in category learning in near (Experiment 1) or far (Experiment 2) transfer. Implications for theories of category learning are discussed.

Keywords: Reminding • Categorization • Declarative concept learning

My daughter and I lived in the coastal and southern part of China, where it has a typical sub-tropical climate. Before we came to Tucson, we had never seen saguaro. So, she was amazed when she saw the giant saguaro for the first time. At that time, she was 5. After searching for similar objects she had seen before, she told me they were a green robot because they had a head and a body, and arms. Then, she changed her idea saying they were not robots because these robots were not on the bus or in the restaurants to help bus-riders and customers. It was until months later when she saw many lower classifications of this type of plant in the desert, and she came to realize these plants have thorns, spines, and colorful flowers and only live in desert earth. Therefore, it was through retrieving and comparing encounters with hedgehog cacti, prickly pear, etc., she created the new category of the cactus family for these plants. The category knowledge guided her to recognize this sort of plants, even in groceries when the plants were for sold for food. Not only in daily life occasions, but the retrieval and comparison also occur in formal educational settings. When learning a new concept, learners may recall a similar example they have studied and compare the current example and the previous example. The comparison of the two examples enables them to learn category knowledge and apply the knowledge to classify a new example. In these scenarios, learners use prior experiences to solve a new problem by reminding. In this study, we were interested in the role of remindings in knowledge transfer.

Remindings

Remindings are stimulus directed retrievals of prior specific episodes (Tullis, Braverman, Ross, & Benjamin, 2014). Remindings significantly modify memory by making dormant information retrievable and accessible (Benjamin &

Ross, 2010). Remindings reduce the space and time between the earlier learning instance and the later learning. Remindings boost memory for temporal order (Jacoby & Wahlheim, 2013) and memory for a change (Wahlheim & Jacoby, 2013; Jacoby, Wahlheim, & Kelly, 2015).

In addition to boosting memories, remindings promote categorization and generalization (Ross, 1984; Ross et al., 1990). By retrieving a relevant instance, people may notice the similarities between the past and current instances and use the prior instance to help categorize the current instance (Ross et al., 1990; Reeves & Weisberg, 1994). Remindings also induce the contrast between the studied and the current instances and therefore support categorization between categories (Ross & Kennedy, 1990; Tullis & Goldstone, 2016). Remindings help people generalize knowledge to solve a new math problem (Ross & Bradshaw, 1994). In learning proverbs, remindings helped learners identify unstudied proverbs that shared the same meaning as studied proverbs (Tullis & Goldstone, 2016). Remindings also play an important role in resolving ambiguity. For example, remindings help people interpret ambiguous stimuli in a sentence (Tullis et al., 2014). Comparing the similarities and contrasting the differences in remindings allow learners to transfer knowledge to solve different problems (Tullis & Goldstone, 2016).

Even though the benefits of remindings in learning have been well acknowledged in many varied tasks, their effectiveness in declarative concept learning has remained an open question. In this thesis, I examined whether remindings support learning declarative concepts. Declarative concepts explain facts or information or describe things, events, or processes, their attributes, and their relation to each other (Zamary & Rawson, 2018). Declarative concept learning is commonly required in classroom lectures and textbooks. A popular practice in learning and teaching a declarative concept is using examples to explain a concept (Zamary & Rawson, 2018). Using examples provides a context to illustrate a concept and thus beneficial in the concept learning (e.g., Rawson, Thomas, & Jacoby, 2015; Zamary & Rawson, 2018). Remindings may also play an important role in learning declarative concepts for the following three specific reasons.

Remindings and declarative concepts

Remindings couple and extend the benefit of comparison and exemplar-based learning approaches (for a review, see Ross, 1984; Ross et al., 1990; Benjamin & Tullis, 2010; Tullis & Goldstone, 2016). First, the advantage of remindings arises from retrieving earlier episodes and comparing across episodes when learners encode later related episodes (Benjamin & Tullis, 2010, Tullis & Goldstone, 2016). In remindings, learning is promoted through retrieving specific studied instances (Ross, 1984). When being reminded of prior learning materials, learners represent the current learning materials and previously studied instances in mind simultaneously. The coupled representations of relevant learning materials make learning more effective. For this reason, remindings are assumed to be more beneficial in learning factual, and specific knowledge, for example, to learn a declarative concept.

Second, remindings benefit learning via retrieving examples stored in long term memory (Ross, 1984). In reminding approach, learning is on the basis of retrieving prior studied materials in memories. However, comparing across two examples simultaneously requires instances only exist in short-term memory. Tullis and Goldstone (2016) showed that the mnemonic benefits of reminding persisted over a one-week retention interval. Remindings help learners focus on encoding specific episodes, which helps learners memorize the learning materials. Comparison, on the other hand, focuses on pattern generalization at the expense of memory for the learning materials. Because remindings work with the information stored in long-term memory, remindings should be more effective in the retention of learning material and knowledge categorization in declarative concept learning. For example, learners need to retrieve materials about a declarative concept they studied when they are tested on the concept in a final exam. Therefore, there exists a lag between the learning occasion and application occasion. We expected that the feature of remindings dealing with episodes in long-term memory fits declarative concept learning.

The advantage of spaced learning over massed learning may be another reason for the effectiveness of remindings in learning a declarative concept. Remindings may benefit memory from spacing repetitions out in time. Spacing learning materials renders the learning materials spread out over time rather than massed together (Whitten & Bjork, 1977; Roediger & Karpicke, 2006; Roediger & Karpicke, 2011). The benefit of spacing compared to massing have been reported for learning mathematical procedures (Rohrer & Taylor, 2007), arithmetic skills (Richard, Lau, & Pashler, 2008), foreign language vocabulary (Logan, Roediger, & McDermott, 2010) and functional relation learning (McDaniel, Fadler, & Pashler, 2013). Morehead, Dunlosky, Rawson, Bishop, and Pyc (2018) reported when participants studied using a spaced technique across sessions versus massed within a single session, participants with spaced practice reported more strategy shifts used for each item than the massed group of participants. Roediger and Karpicke (2011) explained that spaced learning benefits from a retrieval process modifying the representation of the items in memory. For example, when we search for the location of the contents we saved in a computer, we decode our memories in terms of under what topic we saved the documents, at what time we saved them, and for what reasons we needed to save them, etc. The retrieval process is actually a process that we modify and reconstruct our knowledge (Blunt & Karpicke, 2014).

Third, remindings include an effortful retrieval, which is supposed to make learning additionally effective. In remindings, learners may spend more cognitive effort retrieving materials to make comparisons than when they study concurrent examples. An effortful retrieval of a previous example boosts memory more for the first instance in later learning (Tullis et al., 2014). When retrieval involved more challenging and complex processes, the effects on later recall were much greater (Craik and Lockhart (1972). Retrieval will be more beneficial for later recall if more attention is involved or more difficult retrieval is engaged (e.g., Appleton-Knapp, Bjork, & Wickens, 2005; Benjamin & Ross, 2010). Moreover, the retrieval of the earlier examples prompts learners more actively to compare across instances and generalize knowledge across the learning episodes (Tullis & Goldstone, 2016). We believe that the retrieval effort would also render more effective learning of declarative concepts.

Operation of remindings

Across two experiments, I attempted to manipulate the amount of remindings in order to examine whether remindings benefit the learning of declarative concepts. It was expected that learners can have better category knowledge when remindings happen because remindings support comparison and contrast across the learning episodes (for a review, see Ross & Bradshaw, 1994; Benjamin & Tullis, 2010; Tullis et al., 2014; Tullis & Goldstone, 2016).

The probability of reminding increases as the similarity characterized by the learner between the current situation and earlier situation increases (Spalding & Ross, 1994; Tullis et al., 2014). The underlying assumption is that a later situation works as a stimulus for searching memory for its best match in prior learning. When the similarity between two learning instances decreases, it will be harder for learners to be stimulated to look for a prior learning instance that is relevant. Following this logic, I presented similar superficial examples (termed as similar example stimulus condition) or superficially different examples (termed as different example stimulus condition) in the study phase. If the two examples were superficially similar, the later example should prompt retrieval of the earlier studied example. This is a reminding-encouraging situation, in which remindings were more likely to occur. If the two examples were presented superficially differently, it was expected as a reminding-discouraging context with remindings less likely to happen.

This study tested the hypothesis that remindings would enhance learning declarative concepts in near knowledge transfer and far knowledge transfer. By near transfer, I meant the knowledge is applied to a more similar context (Brown & Kane, 1988). Far transfer is when knowledge is broadly extended to a dissimilar context (Barnet & Ceci, 2002). In Experiment 1, reminding examples of a declarative concept was expected to support classifying a novel and similar example within the concept category. Since the original example and the test examples were similar, it was a near transfer. In Experiment 2, reminding examples of a declarative concept was supposed to benefit categorizing a novel but different example. The original example and test examples were different. Thus, it was regarded as far transfer.

Experiment 1

In Experiment 1, the effectiveness of remindings in near transfer in declarative concept learning was assessed. The amount of remindings were manipulated by presenting either similar or different examples during learning. The underlying logic was a similar example stimulus may elicit remindings of studied examples, which would facilitate near transfer. In the different example stimulus condition, remindings would be harder to occur because of the differences between the examples. Fewer remindings would hinder learners from generalizing across studied examples and abstracting important information from examples. With this assumption, it was predicted that the performance of knowledge near transfer would be greater under the similar example stimulus condition over the different example stimulus condition.

Participants

A G*power analysis was conducted to determine how many participants were needed to detect a medium effect (Cohen's d = 0.5) with 0.8 power and an alpha of 0.05 (Faul, Erdfelder, Lang, & Buchner, 2007). G*Power suggested that 34 participants are needed. So, we recruited thirty-four undergraduate students in a class of Introductory Educational Psychology at the University of Arizona to participate in exchange for partial course credit. Also, we recruited paid participants with payment at 20 dollars an hour.

Materials

Twelve declarative concepts were selected from social psychology and decision making, as have been used in prior research (Rawson & Dunlosky, 2016). For each concept, I created four superficially similar examples and one superficially different example. Superficially similar examples had similar story lines and sentence structures (Ross, 1987). Superficially different examples had different story lines and sentence structures, but still illustrated the same concept (Ross, 1987). The examples used for sunk costs fallacy are listed in Table 1.

Design

This study used a within-subjects design to test the impact of similar and different examples on the learning of declarative concepts. For each participant, half of the concepts were randomly assigned to the similar condition and half to the different condition.

Table 1

Sample of examples used in Experiment 1

Concept	Sunk Cost Fallacy
Original example	Costco spent $10 billion developing a product before realizing Walmart had already developed the product. Costco decided to continue the project because the $10 billion had been invested.
Study phase	SS: Amazon invested $20 billion in launching a new service before they discovered Alibaba had done so already. Amazon decided to continue the project because they had already invested so much money.
	SD: Jamey is not happy with his long-term relationship, but he stays in it because he has already devoted 5 years to it.
Test phase	SS: Apple spent $500 million in developing a new application program but then found the program had been developed by Google. Apple decided to continue the program development because of the $500 million they had invested.
	SS: Toyota invested $8 billion in developing a new SUV before realizing Hyundai already developed a similar car. Toyota decided to continue developing the SUV because of the investment they have made.
Note. SS means superficially similar examples (examples with similar story lines and structures); SD means superficially different examples (examples with different story lines and structures).	

Procedure

The participants read and signed a consent form before they entered the experiment. They were informed they would learn a set of concepts and the memory for these concepts would be measured. The lab had four desktop computers to hold up to 4 participants simultaneously.

First, the participants were asked about their prior knowledge for each of the 12 to-be-learned concepts. Concept names were presented one at a time, and the participants reported anything that they knew about the concept. If the participants thought they did not know about the concept, they were instructed to type “NONE”. Next, the participants studied all the 12 concepts one at a time in a random order. The concept name, definition, and original example were presented on the screen. When finished studying each concept, the participants pressed any key to move to the presentation of the next concept. After studying all the concepts once, the participants re-studied each concept one at a time in a new random order.

During re-study, the concept name and a second example was presented to participants. For half of the concepts, the second examples were superficially similar to the originally studied examples; for the other half, the examples were superficially different than the original examples. The participants were asked whether the current example made them think of a prior studied example. If the participants thought of a specific prior studied example, they were instructed to type in all the prior example. If the participants could not think of any prior studied example, they just typed in “NONE”.

After re-studying all the 12 examples of the concepts, the participants were immediately given an example classification test and an example naming task. In the example classification task, the participants were provided a new example that was superficially similar to the original example and asked to type in the corresponding concept name. The 12 new examples were tested in a random order. Then, the classification task was repeated with new similar examples of each of the 12 concepts in a new random order, such that two novel examples were tested for each concept. In the definition task, the participants were given the definition of a declarative concept that they had studied in the study phase and then were asked to type in the name of the concept for the example.

Results

Data coding. Two researchers coded the data about prior knowledge, reminded examples, example classifications and definition naming separately. All the coding was done blinded to the experimental conditions. After the separate coding of the data, the two researchers discussed the different coding, and made agreement on the final coding. The information about the reliability between the two raters is shown in Table 1. To check the prior knowledge of the declarative concept, we coded based on whether the participant had the correct knowledge of the concept. If they provided the correct knowledge about the concept, we would code it as 1. Otherwise, it would be coded as "0". The two raters initially agreed on 89% of the coding (see Table 2).

We then coded whether participants correctly retrieved the reminded examples during the study phase. Each studied example was divided into two parts. Take the example of "Regina bought a new bike. Just because she owns it, she thinks her bicycle is more valuable than her friend's identical bike" to illustrate coding scheme. In this example, one component of the example was "Regina bought a bicycle" and the second component was "she thinks her bicycle is more valuable than others'." We coded each component as either a 0 (if they did not recall the component) or 1 (if they did recall the component). In the first time of grading, the agreement percentage of the two graders was 89% for action 1, and 91% for action 2 (see Table 2).

When coding the test example classification and the test definition naming, we focused on whether the correct concept name was provided and ignored the spelling or switch of the word order of a concept. For example, we still counted it as a correct answer when decision avoidance was written as avoiding decision making. The coding reliability for test example classification was 97% for test example classification 1, 99% for test example classification 2, and 99% for definition example (see Table 2).

Table 2

Coding reliability between two raters in Experiment 1 and Experiment 2.

	Prior knowledge	Action1	Action 2	Test example 1	Test example2	Definition naming
Exp. 1	0.89	0.89	0.91	0.97	0.99	0.99
Exp. 2	0.89	0.89	0.89	0.97	0.98	0.99

Study time. The mean time spent in studying each item under the similar example stimulus condition (M_{similar}=16.65, SD_{similar}= 6.54) and under different example stimulus condition ($M_{\text{different}}$=16.81, $SD_{\text{different}}$=6.80) was similar, $t(33)= 0.28$, $p=.78$, Cohen's d=0.02. Since the study time spent under the two experimental conditions did not differ, we would not consider the factor in the following analysis.

Reminding. First, we excluded the trials on which an individual had prior knowledge from analyses. The coding results showed 26 out of 408 (6.3%) items were cases in which the participants had correct knowledge about the concept. Second, the patterns of remindings of Action 1 and Action 2 of the studied examples were investigated to see whether it was reasonable to average the reminding performance of the coding for Actions 1& 2. Out of all possible examples, only 14.92% of remindings involved remembering only one of the two actions. The correlation between remindings of Action 1 and Action 2 was r =.72. The results indicated that the case of half remindings only accounted for a small amount of the remindings. Also, most of the participants showed a tendency that if they recalled one action of each example, they would recall the other one, or they just recalled none. Therefore, it was reasonable to combine the separate coding of Action 1 and Action 2. We merged the data of Action 1 and Action 2 in remindings by averaging the coding of them (0= not correct reminding, 1=correct reminding). The averaged score of each reminded example became 0 (no remindings of Action 1 or Action 2), 0.5 (half reminding: either recall of Action 1 or Action 2) and 1 (full reminding of both Action 1 and Action 2). Last, we computed the proportion of examples that were reminded under the similar example and different example conditions. The proportion of examples that are recalled during study is shown in Figure 1. The amount of recall of the original examples during study of later examples (i.e. remindings) of under similar and different conditions is shown in the left of Figure 1 below. The difference between conditions was not statistically significant, $t(33)= 0.43$, $p=.67$, Cohen's d=0.05.

Example classification. The proportion of accurately classified examples was computed for each participant in the similar example stimulus condition and the different example stimulus condition (see Figure 2). Since the performance of the participants across both test examples showed a similar pattern, I averaged the performance of the participants in the two example tests. No significant differences were detected in the outcomes of the test example classification across the two conditions, $t(33)= 1.35$, $p=.19$, Cohen's $d=0.19$.

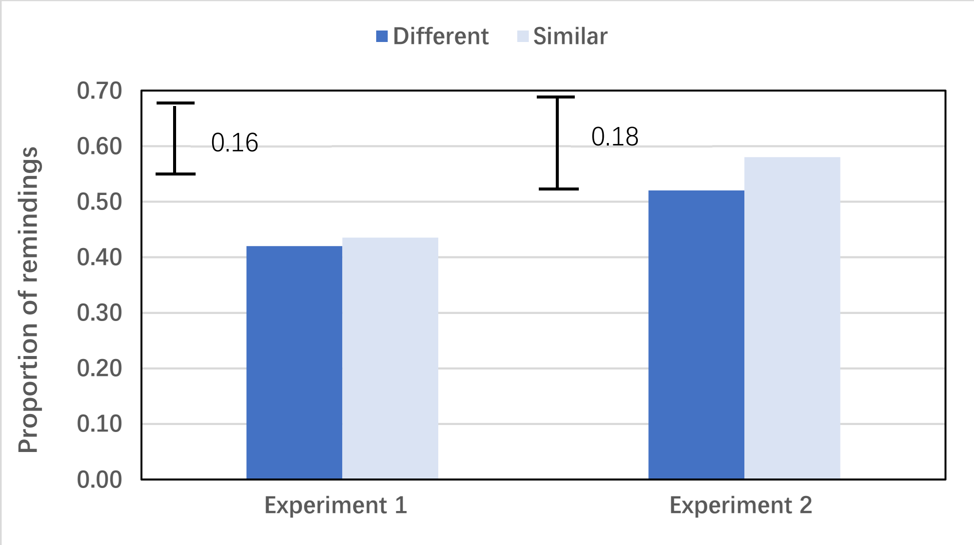
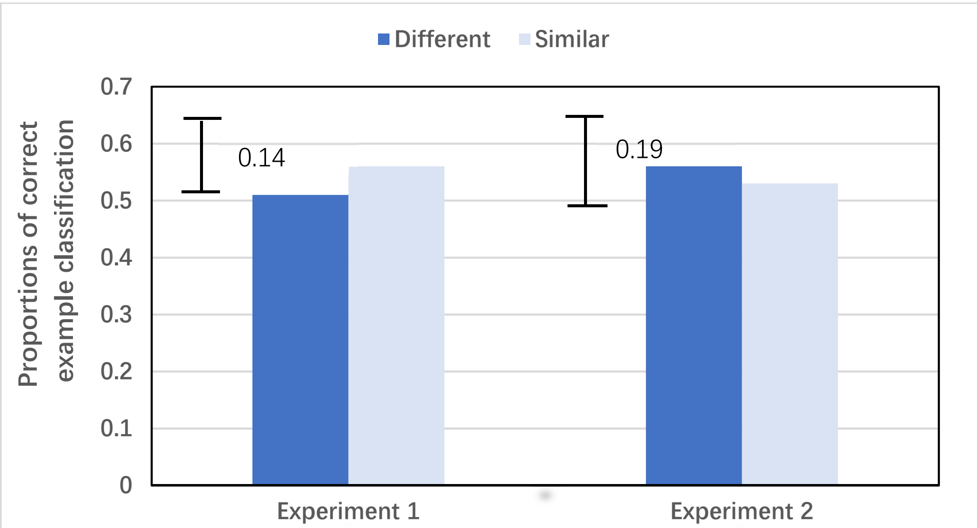
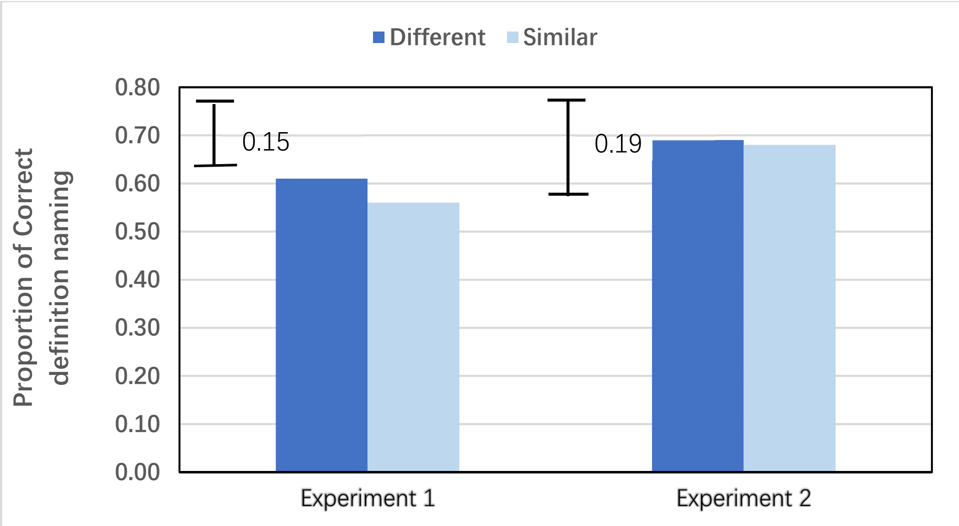


Figure 1. The proportion of reminded examples under the condition of different example stimulus and similar example stimulus in Experiment 1*(left)* and in Experiment 2*(right)*. The error bars show 95% confidence intervals of the difference between different and similar conditions for each experiment.



(n=34)

Figure 2. The proportion of correct test example classification under the conditions of different example stimulus and similar example stimulus in Experiment 1*(left)* and in Experiment 2 *(right)*. The error bars show the 95% confidence intervals of the difference between different and similar conditions for each experiment.



(n=34)

Figure 3. The proportion of correct definition naming under the conditions of different example stimulus and similar example stimulus in Experiment 1 (*left*) and in Experiment 2 (*right*). The error bars show 95% confidence intervals of the difference between different and similar conditions for each experiment.

Definition naming. The ability of participants to identify or name the concept is shown in Figure 3. No significant difference was found between the similar and different conditions, $t(33)= 1.43$, $p=.16$, , Cohen's $d=0.16$.

Remindings and test performance. The major goal of the experiment was to explore whether the reminding of a studied example would result in better learning of declarative concepts. Given that the study conditions (i.e. the similarity between studied examples) did not significantly affect the amount of remindings, I explored how remindings affect concept learning by conditionalizing whether or not remindings occurred. I classified the reminded example at three levels: no correct recall, half recall, and full recall. The performances of test examples and definition naming were examined under the three levels. The results did not show a clear pattern that the remindings at different degrees resulted in differential learning outcome across in example classification (see Figure 4) and in definition naming (see Figure 5). Overall, full remindings of the studied examples did not lead to a better learning outcome in both example classification and definition naming.

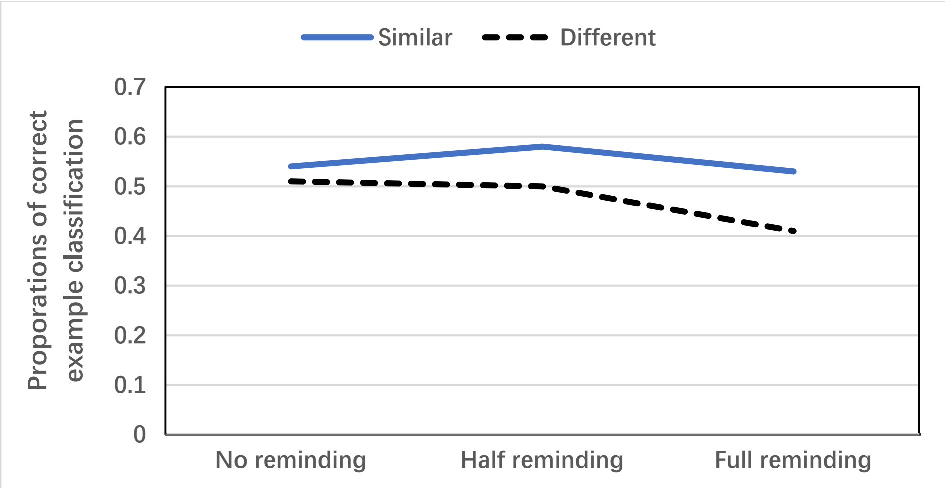


Figure 4. The proportion of correct example classification at different degrees of remindings in Experiment 1.

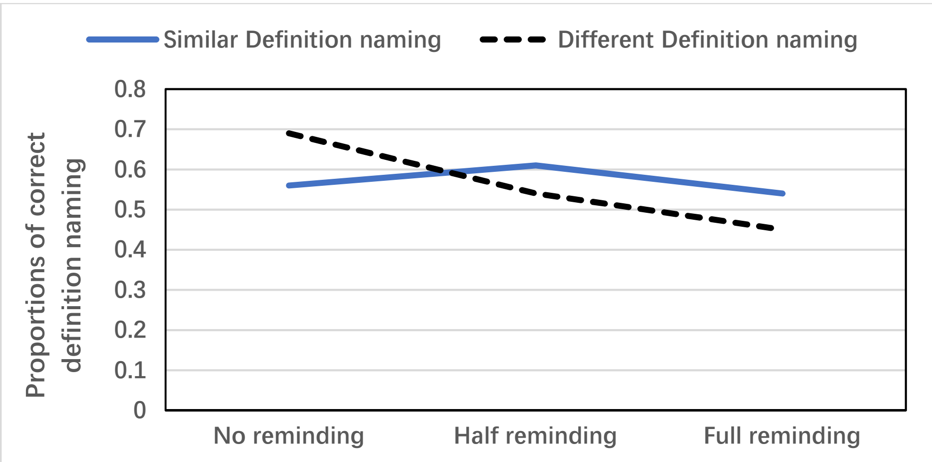


Figure 5. The proportion of correct definition naming at different degrees of remindings in Experiment 1.

Discussion

In Experiment 1, we investigated whether similar or different examples supported concept learning through remindings. Participants did not differ the reminding performances under a superficial similar stimulus vs. under a superficially different stimulus. The results suggested both superficially similar examples and superficially different examples enabled participants to recall the earlier studied examples in the study phase. One reason could be what matters in remindings is only whether stimulus and the target are associated. The association between the current learning and the former learning prompts the learners to encode the shared information between the two learning instances.

We did not find the differential learning outcomes in example classification and definition naming in the test phase between the similar example stimulus and different conditions (see Figure 2 and Figure 3). It was not a surprising result when remindings were prompted comparably under the two experimental conditions. Learning of the declarative concepts in near transfer benefited from remindings no matter what associations of prompts had triggered the retrieval.

However, this conclusion was questioned when we had the results of the follow-up analysis (see Figure 4). In the analysis, we did not find the degree of remindings— no remindings, half remindings, and full remindings brought about incrementally increasing learning outcomes. In fact, participants even learned category knowledge and remembered the definition studied when they did not retrieve the previous examples at all (no remindings). Thus, our tentative conclusion from Experiment 1 was that remindings, at least, were not the only factor that supported the near knowledge transfer in declarative concept learning.

Experiment 2 was driven by the motivation to examine whether the different reminding conditions would result in a different type of knowledge transfer— far transfer. Far transfer is when knowledge is broadly extended to a dissimilar context (Barnet & Ceci, 2004). Repetition and variability of the studied materials lead to differential category knowledge learning in near transfer and far transfer (Wahlheim, Finn, & Jacoby, 2012). Wahlheim et al. (2012) found that when the presentations of the bird were highly repetitive with the same bird presented 6 times in the study phase, the participants showed a high classification performance for the studied birds.

However, when the bird presentation was of highly variability with 6 different types of birds presented, the participants demonstrated a better classification performance when they encountered a novel type of bird in the test phase. The similarity of the studied materials supported near transfer of knowledge and variability of the studied materials promoted far knowledge transfer in category learning. In Experiment 1, it was found both similar example condition and different example condition benefit remindings, but remindings were not the only predictor of near transfer learning. In Experiment 2, I examined whether remindings under the two conditions (similar vs. different) might benefit far knowledge transfer.

Experiment 2

Experiment 2 was to explore whether remindings would facilitate far knowledge transfer. To examine the far knowledge transfer, I tested whether the participants could correctly classify a new scenario with a concept when the new example was superficially different from the one they studied.

Participants

A power analysis was conducted using G*Power to decide the number of participants needed. The G*Power test was set similarly as Experiment 1 to detect a medium effect (Cohen's d = 0.5) with 0.8 power, an alpha of 0.05 (Faul, Erdfelder, Lang, & Buchner, 2007). It was shown by the G*Power test that we needed thirty-four participants. So, another 34 undergraduates enrolled in psychological classes were recruited for partial course credits.

Methods

Experiment 2 proceeded identically to Experiment 1 except for one major difference: the classification test examples were different in story and structure from any studied examples. The examples in the study phase and test phase are shown in

Table 3.

Results

Data coding. Data coding was the same as that in Experiment 1. The same two researchers had blind coding separately. We coded the data of prior knowledge, reminded examples, test example classification and definition naming. All the data coding and grading were checked between the second rater. The interrater reliability information for prior knowledge coding, action 1 and action 2, and definition naming is shown in Table 2.

Table 3.

Sample of examples used in Experiment 2.

Concept	Sunk Cost Fallacy
Original example	Costco spent $10 billion developing a product before realizing Walmart had already developed the product. Costco decided to continue the project because the $10 billion had been invested.
Study phase	SS: Amazon invested $20 billion in launching a new service before they discovered Alibaba had done so already. Amazon decided to continue the project because they had already invested so much money.
	SD: Jamey is not happy with his long-term relationship, but he stays in it because he has already devoted 5 years to it.
Test phase	SD: Georgia has a magazine subscription. She doesn't enjoy reading the magazine, but she reads the magazine each month because she already paid for the subscription.
	SD: A woman spends $300 on a dress and at home tries it on again but it does not fit. She looks awful in it. She is reluctant to get rid of it because she spent so much money on it.
Note. SS means Superficially similar examples (examples with similar story lines and structures); SD means Superficially different examples (examples with different story lines and structures).	

Study time. The mean time spent in studying each item under the similar example stimulus condition ($M_{similar}$=13.97, $SD_{similar}$= 6.24) and under different example stimulus condition ($M_{different}$=14.26, $SD_{different}$=6.82) was similar, $t(33)$= 0.05, p=.96, Cohen's d=0.05. Therefore, the study time was not considered in the following analyses.

Remindings. Prior knowledge data showed that 18 out of 408 (4.4%) of the items that the participants had the knowledge. The items that the participants had the prior knowledge were excluded from all the following statistical analysis. Then like in Experiment 1, it was necessary to see whether it was proper to average the performance of reminded Action 1 and Action 2. Out of all the possible remindings, only 13.85% involved remembering only half of the studied example. The correlation between remindings of Action 1 and Action 2 was r =.74. The case of half remindings correctly recalled was only in a small fraction of the remindings. Most of the participants were either reminded of two actions of the example or were not reminded of any. Therefore, I averaged the coding of Action 1 and 2 and created a new column with the values of 0 (no remindings), 0.5 (half reminding) and 1 (full remindings). Last, the coded performance of action 1 and action 2 was averaged and was put in a new column for the reminding performance of the participants under the two conditions. The performance of the reminded examples is reported in Figure 1. The amount of remindings under similar condition and different conditions was not significantly different, $t(33)$= 1.15, p=.26, Cohen's d=0.22.

Example classification. The proportion of the accurately classified examples for each participant was calculated under similar example stimulus condition and different example stimulus condition (see Figure 2). The performance of the participants was in a similar pattern in the two test examples, so the performance was averaged in the two tests. No significant differences were found between the two condition in classifying new examples (t(33)= 0.51 , p=.61, Cohen's d=0.16) .

Definition naming. Finally, no significant difference was found between conditions in the ability of participants to name the definitions of concepts, t(33)= 0.30 , p=.76, Cohen's d=0.18 (see Figure 3).

Remindings and test performance. As in Experiment 1, I also analyzed whether the degree of reminding during study affects later test performance. The reminded examples were subset into no reminding, half reminding, and complete reminding based on the coded data. No clear pattern emerged from the data (see Figures 6 and 7).

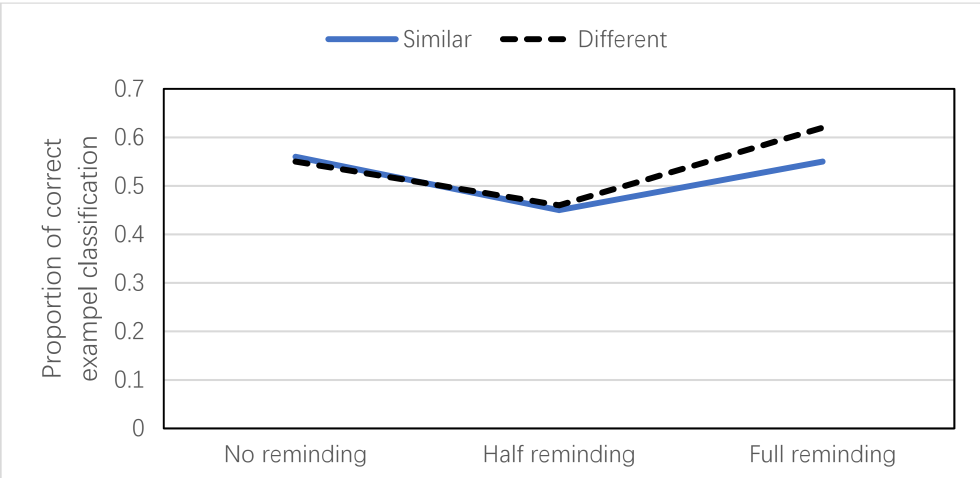


Figure 6. The proportions of correct example classification at different degrees of remindings in Experiment 2.

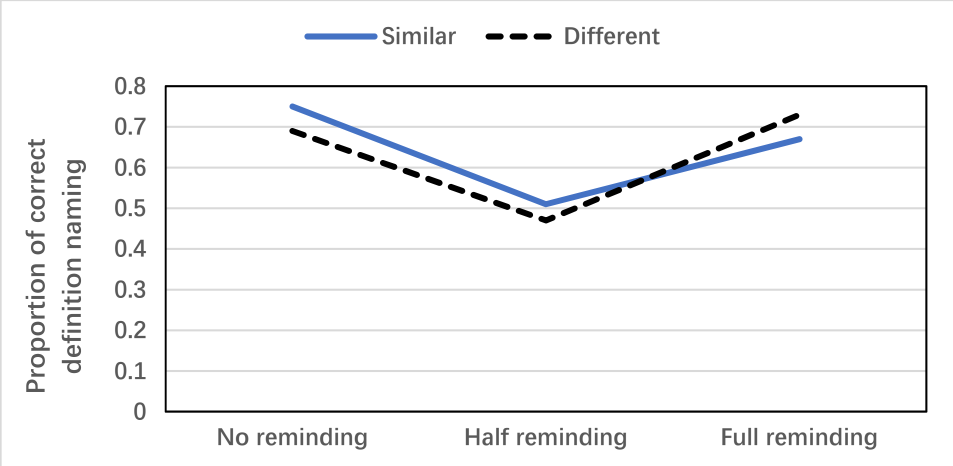


Figure 7. The proportions of correct definition naming at different degrees of remindings in Experiment 2.

Discussion

In testing the role of remindings in far transfer in declarative concept learning, no difference was found in the amount of remindings between conditions. The result was a replication of Experiment 1, indicating both similar and different examples prompted the participants to retrieve studied examples. No evidence was found either that far transfer benefited differently from remindings with similar example stimulus and with different example stimulus. Since there were no differences in remindings, I cannot conclude that to what degree remindings promote concept learning. Second, I found no significant differences in example classification in far knowledge transfer between similar example stimulus condition and different example stimulus condition. The results did not replicate the findings of Wahlheim et al. (2012) statistically, which showed that the variability of stimulus in remindings would benefit far transfer. In Experiment 1, full remindings did not lead to better category knowledge in near transfer. However, in Experiment 2, full remindings led to numerically, though not statistically significant better far knowledge transfer than that at half reminding. However, the participants also learned category knowledge when they did not have correct remindings. The results suggested that in far knowledge transfer, there may be more factors more than remindings alone contributing to the learning.

Combined analysis

A combined analysis was operated to explore whether reminding conditions affected near knowledge transfer and far knowledge transfer differently. Wahlheim et al. (2012) found that repetition in stimuli promoted near knowledge transfer and variety in stimuli supported far knowledge transfer. Inspired by the study, we wanted to examine whether superficially similar reminder and superficially different reminder would work differently in near and far knowledge transfer. In addition, the remindings between Experiment 1 and Experiment 2 demonstrated a difference from observation (see Figure 1). Since the participants in the two experiments were recruited randomly, we were curious to know whether the remindings were statistically different between the two groups of participants and whether there were differences in knowledge transfer and definition naming.

We ran three 2 (stimulus conditions: different vs. similar) × 2 (experiments: Exp 1 near knowledge transfer vs. Exp. 2 far knowledge transfer) mixed effects ANOVAs on remindings, performances on example classification and definition naming. In remindings, the results did not reveal a significant interaction between stimulus conditions and experiments on remindings, $F(1, 66)=0.329$, $p= .568$, $\eta^2_{partial} = 0.005$, a main effect of stimulus conditions, $F(1, 66)=1.299$, $p= .259$, $\eta^2_{partial} = 0.019$, or a main effect of experiments $F(1, 66)= 3.896$, $p= .053$, $\eta^2_{partial} = 0.056$. In the performance of example classification, the results did not show a significant interaction between stimulus conditions and experiments, $F(1, 66) = 1.484$, $p= .228$, $\eta^2_{partial} = 0.022$, a main effect of stimulus condition, $F(1, 66)=0.156$, $p= .694$, $\eta^2_{partial} = 0.002$, or a main effect of experiments, $F(1, 66) = 0.038$, $p= .846$, $\eta^2_{partial} = 0.001$. In the performance of definition naming, there was no interaction between the stimulus condition and experiments , $F(1, 66)=0.428$, $p= .515$, $\eta^2_{partial} = 0.006$, no main effect of stimulus conditions, $F(1, 66)=1.269$, $p= .264$, $\eta^2_{partial} = 0.019$, or no main effect of experiments $F(1, 66)=2.802$, $p= .099$, $\eta^2_{partial} = 0.04$.

The results of the combined analysis of Experiments 1 and 2 suggested that the similar and different stimuli did not have a differential impact on near knowledge transfer and far knowledge transfer. The performances in near knowledge transfer and far knowledge transfer in two experiments did not differ significantly. However numerically, participants did slightly better in near knowledge transfer under similar stimuli condition, and they had also moderately better performance in far knowledge transfer under different stimuli condition (see Figure 2).

General discussion

We examined whether remindings support declarative concept learning. Unfortunately, the primary manipulation (i.e. similar and different examples) did not cause different amount of remindings across conditions. It is, therefore, difficult to draw clear conclusions. I interpreted the data to show three findings.

Similarities and distinctiveness of the stimuli in remindings

The present study suggested both similarities and distinctiveness of the stimuli support reminding. In the experiments, the participants recalled the studied examples under the two conditions of similar example stimulus and different example stimulus. The similarities between current learning and prior learning (similar story lines and surface structures) prompt people to retrieve memories for studied materials. Except for the superficially similar relationship, the stimulus and the target could be related as superficially different. In the present study, when provided a superficially different example with different storylines and different surface structures (distinctiveness between reminder and target), the participants were reminded of the prior example from the studied phase. So, the similarities and distinctiveness of the stimuli can both lead to remindings. The association between a reminder and the target event is at the heart of reminding and no benefits should be apparent for unrelated materials (Benjamin & Ross, 2011, Ross, 1994; Benjamin & Tullis, 2010). The results replicated the results in Tullis, Benjamin, and Ross (2014) about the mnemonic effect of remindings. In Tullis et al. (2014), remindings benefited memory for the prior episodes only when they were related to semantic pairs. This mnemonic effectiveness disappeared when they were repeated or when they were unrelated pairs. In studying the effectiveness of reminders, other-generated reminders also benefited memory because of its distinctive characteristics.

Learning orientations of learners

Previous studies have classified two types of learning strategies used in category knowledge learning: rule-based versus associative reasoning (Sloman, 1996); model-based verse model-free learning (Daw, Niv, &Dayan, 2005); rule-based learning versus example -based learning (McDaniel, Cahill, Robbins, & Wiener, 2014); rule-based and feature-based generalization (Don, Goldwater, Otto, & Livesey, 2016; Wahlheim, McDaniel, & Little, 2016); abstraction learners versus exemplar learners (McDaniel, Cahill, Frey, Rauch, Doele, Ruvolo, & Daschbach, 2018), and generation- based learning and retrieval-based learning (Wahlheim, Finn, & Jacoby 2012).

While labeled in different ways, these dichotomous terms pointed to a common theme— the two orientations for learners to represent the studied materials in mind. In rule-based learning, the symbolic representations of learning materials are formed by learners' encoding and extracting the rules from the studied materials (Sloman, 1996). The higher-order processes of learning tend to be more pattern driven but stimulus-free (Evans & Stanovich, 2013). They are abstraction learners. In the tasks testing near transfer and far transfer, these abstraction learners were more likely to extrapolate into a related but notably different context (McDaniel et al., 2014). In exemplar-based learning, the associated representations were established on learners' comparison and then the summation of the shared features of the learned examples (McDaniel et al., 2018). Exemplar-based learners are much more stimulus-driven in representing the category knowledge than abstraction learners (Don et al., 2016). In the test of knowledge transfer, the exemplar-based learners were less successful because they tend to interpolate between the repetitive aspects of the items in the study phase (McDaniel & Fadler, & Pashler, 2013).

The results of the current study may provide evidence that both the symbolic and associative representations of knowledge can be generalized to new learning. In this study, the performance of category knowledge learning was almost independent of the degrees of no remindings, half remindings, and complete remindings. With that being said, exemplar-based learners relied on recalling the facts of the studying examples (stimuli) in both far knowledge transfer and near knowledge transfer. The abstractor learners opted for a pattern-driven learn the process by focusing on extracting rules in stimulus encoding. These preferences were regarded as individual differences in choosing learning strategies (McDaniel et al., 2014; McDaniel et al., 2013).

Declarative concept learning

If individual differences of exemplar-based learners and abstractor learner alone can provide an overarching explanation, it will be hard to explain why learners did not choose to be an abstractor learner but learned more as exemplar-based learners in previous reminding studies (e.g., Ross, 1984; Ross & Bradshaw, 1994; Tullis, Braverman, Ross, & Benjamin, 2014; Tullis & Goldstone, 2016). In those studies, learners demonstrated better learning outcomes only when remindings were prompted under similar stimulus conditions. Then, what has made the effectiveness of remindings inconsistent between the current study and the prior literature?

The explanation to this question is except for individual differences in learning strategies preference, learning materials may also have an interaction with the learning strategy choice. The interaction caused that learning happened at the conditions of both no remindings and full remindings. Though most of the declarative concepts used in the study were not learned by the participants (as the prior knowledge check showed), it is still possible that they have already had extensive experience in learning declarative concepts. In this sense, they are expert learners in learning declarative concepts. As an expert learner, they are more likely to adopt abstraction learning strategies when studying the materials. When they are familiar with the relevant knowledge in that specific field, learners can save more cognitive resources to process abstract patterns. The efficiency in cognition has an impact on the choice of learning strategies to be more rule-based or to be more example-based (Don et al., 2016; Wahlheim et. al, 2016; Daw et al., 2005). Lewandowsky,Yang, Newell, and Kalish (2012) suggested that working memory compacity is more important for categorization response strategy in some tasks than in others. At least, the results of the current study suggested that the extensive learning experiences in declarative concepts in social sciences frees up learners' cognitive resources. This would allow the learners to choose the learning strategies they prefer— to be more reliant on rule-based learning or to be more reliant on example-based learning.

This study has theoretical implications in the study of reminding. It provided evidence that remindings can arise from similarly associated and also differently-associated stimuli. This study is implicational in teaching and learning. When teaching declarative concepts, the instructors may provide both superficially similar and different examples. The instructor also will take individual differences in learning strategies into consideration. For exemplar-based learners, they prefer to use examples to learn; while for the abstractor learners, they may opt for patter-driven comparison and contrast in learning.

In future studies, it might be necessary to create more sensitive manipulations for reminding encouraging and reminding discouraging conditions in learning. The conditions to prompt or hinder remindings might be changed to related and unrelated pairs (for a review, see Tullis, Benjamin, & Ross, 2014). We may also consider setting up a control group to pinpoint the role of remindings. The control group will be provided the same examples across the study phases and will not be asked to remind of the example they studied. The control group will help tease out the factor that the participants may have reminded the examples but just do not provide the remindings correctly or they just do not want to provide any remindings. This might be the case that happened to the participants in this study. The participants reported no correct remindings and but still learned. It was hard to tell whether the remindings happened or not in their case. Thus, it is hard to conclude the effectiveness of remindings in the learning. Also, the potentially interactive role of learning materials will be more thoroughly considered in future studies. We can compare the learners when they study the type of materials they have already had the learning experiences before vs. when study the materials that are relatively new to them. For example, the participants in the social sciences are asked to learn psychological concepts vs. math concepts. We may also ask the learners to study examples of concepts vs. to study confusable concepts. In this way, it might be able to pinpoint the role of remindings in declarative concept learning in a more specific learning situation.

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